

MEMORANDUM

TO: Leaking Underground Storage Tank (LUST) Staff

FROM: Kent P. Gray, Executive Secretary (UST)
Utah Solid and Hazardous Wastes Committee

DATE: December 11, 1990

SUBJECT: Use of the Guideline Document for Estimating Numeric Cleanup Levels for Petroleum-Contaminated Soil at Underground Storage Tank Release Sites.

Attached is a document entitled "Estimating Numeric Cleanup Levels for Petroleum-Contaminated Soil at Underground Storage Tank Release Sites." This document is a compilation of available references on the potential health and environmental impacts of petroleum-contaminated soils. I recommend that the information contained in this document be used in your evaluation of LUST sites on a case-by-case basis for determining appropriate cleanup levels, as provided for in UAC R450-101. This document is only a recommended guideline, and does not establish absolute standards. A determination of appropriate cleanup levels for soil should consider the information contained in this document, together with other site-specific information as specified in the Bureau's cleanup policy contained in UAC R450-101.

MEMORANDUM

TO: Kent P. Gray, Executive Secretary (UST)
Utah Solid and Hazardous Wastes Committee

THROUGH: Bryan Whitaker, Manager

Underground Storage Tank Branch

FROM: Robin D. Jenkins, Environmental Health Scientist

Underground Storage Tank Branch

DATE: December 11, 1990

SUBJECT: Guidelines for Estimating Numeric Cleanup Levels for Petroleum-Contaminated Soil at Underground Storage Tank Release Sites.

The attached document is provided pursuant to your request for the development of numeric cleanup levels for petroleum-contaminated soil at leaking underground storage tank (LUST) sites. The document was compiled from the references listed and represents a staff review of the available information for determining the impact of petroleum-contaminated soil on human health and the environment. The purpose of this document is to describe how cleanup levels can be estimated on a site-specific basis, pursuant to the requirements of R450-101, Cleanup Standards. The numeric cleanup levels are based on the best available scientific information, and should be applied on a case-by-case basis.

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GUIDELINES FOR ESTIMATING NUMERIC CLEANUP LEVELS FOR PETROLEUM-CONTAMINATED SOIL AT UNDERGROUND STORAGE TANK RELEASE SITES

EXECUTIVE SUMMARY

Utah Administrative Code (UAC) R450-101-4, Cleanup Standards, requires that corrective action be initiated at sites where releases from underground storage tanks (USTs) have occurred. The Rule specifies that in the absence of existing applicable cleanup standards, sites must be characterized by applying Evaluation Criteria so that appropriate cleanup levels can be established.

R451-205 (UAC) requires the analysis of total petroleum hydrocarbons (TPH) of samples collected from sites where underground storage tanks (USTs) are taken out of operation. The Rule also requires that other petroleum-related constituents be analyzed if TPH contamination is documented. It is, therefore, necessary that guidelines for soil cleanup be established in order to effectively direct corrective action, and meet the requirements of the aforementioned Rules.

Recommended soil cleanup levels (RCLs) provide the necessary guidelines for conducting consistent site evaluations and determining appropriate corrective actions. Guidelines allow flexibility for evaluations on a case-by-case basis when maximum contaminant levels (MCLs) are not in place. RCLs are intended to assist regulators, the regulated community, and environmental consultants in conducting site evaluations, determining the appropriate cleanup levels for a given site based on its level of environmental sensitivity, and implementing corrective action in an environmentally effective, time-efficient, and cost-effective manner.

The proposed guidelines presented in this document are designed to be consistent with and to meet the substantive requirements of the following regulations: (1) Utah Corrective Action Cleanup Standards Policy (R450-101 UAC), (2) Utah Groundwater Quality Protection Regulations (R448-6), (3) Utah Air Conservation Regulations, and (4) The Code of Federal Regulations, Title 40 (40 CFR), Subpart F, Part 280.60 to 280.66, Release Response and Corrective Action for UST Systems Containing Petroleum or Hazardous Substances.

Figure 1 is a decision flowchart that presents the process by which releases of petroleum products from USTs are identified, characterized, and remediated. A release that is reported or discovered undergoes an initial screening process to determine if the concentrations of contaminants can be safely left in place. The Code of Federal Regulations, Title 40 (40 CFR), Part 280.60 to 280.66 (Subpart F) requires that abatement, characterization, and corrective action measures be performed, documented, and submitted in report form within specific time frames following a release. The procedures presented in this document are consistent with those regulations.

This document is divided into four sections that address the following: (1) Purpose and scope of evaluating releases from USTs; (2) Background information, such as the properties and

characteristics of petroleum products, regulatory guidance levels used by various states for petroleum-related constituents, and how cleanup levels are derived from contaminant transport and fate models; (3) the initial screening criteria used by Utah State UST staff for evaluating the reported contamination at release sites, and suggested appropriate cleanup levels for various degrees of environmental sensitivity; and (4) the staff review of required reports and application of suggested appropriate specific cleanup levels at sites deemed to be contaminated.

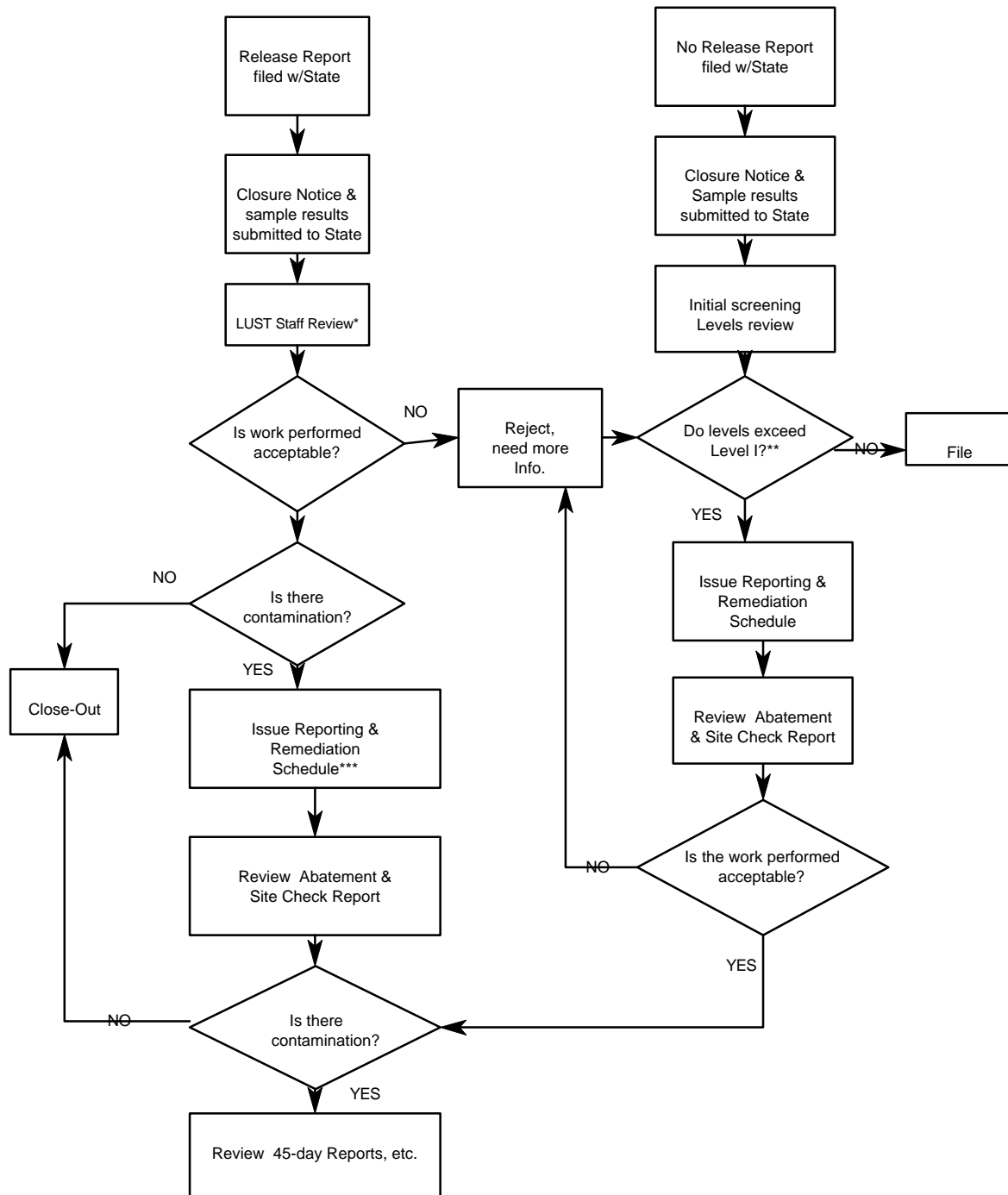
1.0 Purpose and Scope

The development and implementation of numeric Screening Levels and RCLs for the constituents commonly found in petroleum-contaminated soil come none too soon in light of the dynamics of UST management programs. The RCLs presented in this document are intended for use as guidelines for evaluating petroleum-contaminated soil and for determining the potential for migration and impact on human health and the environment. The concentration of petroleum contaminants that can be safely left in place cannot absolutely be quantified for any site of any degree of environmental sensitivity. Some factors that prevent precise quantification include the variability of types and concentrations of constituents in petroleum products, lithologic heterogeneity of the contaminated media, and the inherent uncertainty associated with establishing representative exposure pathways. The lack of precision and inability to quantify safe levels of petroleum-contaminated soil may give rise to extenuating circumstances and adjustments to the RCLs for a given site.

The methodology and resulting suggested cleanup levels presented in this paper are tools for meeting the conditions of R450-101 UAC, Cleanup Standards Criteria. The rule requires that health impacts, environmental impacts, economics, and technology be considered when implementing cleanup levels. The proposed RCLs satisfy the first two elements of that rule. Utah State rule R451-205-2(c) requires that gasoline and diesel fuel-contaminated soil be analyzed for the presence of TPH, and that waste oil-contaminated soil be analyzed for oil and grease or total recoverable petroleum hydrocarbons. It is therefore necessary that RCLs for TPH in soil be established and implemented.

This document presents recommended cleanup levels for petroleum-contaminated soil. Groundwater protection levels are described in the Utah Groundwater Quality Protection Regulations (R448-6, Utah BWPC, 1989). Groundwater cleanup standards are currently being developed by the Utah BWPC. Once in place, groundwater cleanup at petroleum release sites will be conducted in accordance with the groundwater cleanup standards.

Figure 1
Decision Flow Chart for a Release Response



* Use Evaluation Ranking Criteria for determining level of environmental sensitivity and soil TPH RCLs

** Level I environmental sensitivity, see Table 9.

*** Use Evaluation Ranking Criteria and require analysis of additional constituents (BTEX, lead PAHs, etc).

The methodology, Evaluation Ranking Criteria, and resulting cleanup levels presented in this document are similar to those developed from contaminant transport and fate models and used by California, Oregon, Arizona, and South Dakota, combined with the application of site-specific factors unique to Utah.

The concentration of TPH that can be left in soil considers the leaching potential of benzene, which is carcinogenic and constitutes a significant percentage of gasoline. The recommended soil cleanup levels presented in this document are based on values derived from contaminant transport and fate models. Those values have then been modified by the scrutiny of RCLs used by other states and EPA Regions, and by applying the best professional judgement of staff scientists experienced with UST management and remediation of petroleum-contaminated soils and groundwater in Utah. The RCLs presented herein are therefore anticipated to be protective of human health and the environment.

2.0 Background Information

Determining appropriate cleanup levels requires a knowledge of the type of petroleum product released, as well as the toxicity, degradability, aqueous solubility, and potential for migration of the constituents comprising the product. The toxicity of constituents in petroleum products is known for only a few constituents. Federally established maximum contaminant levels (MCLs), proposed MCLs (PMCLs), and health-based guidance levels (HBGLs) for petroleum-related constituents in water have been adopted by some states, while other states have imposed water quality criteria more stringent than the federal standards.

This section discusses the characteristics of the various types of petroleum products commonly stored in USTs, the regulatory guidance levels for various petroleum-related constituents, and how soil TPH RCLs are estimated from contaminant transport and fate models.

2.1 Characteristics of Petroleum Products

Petroleum fuels consist of variable mixtures of hydrogen-saturated aliphatic hydrocarbons, unsaturated alkenes, and alkynes, volatile aromatic, and polynuclear aromatic compounds (PAHs). The degradation of alkanes, alkenes, and alkynes depends on their molecular weight, vapor pressure, water solubility, number of double bonds, degree of branching, and whether the compound's configuration is straight-chain, branched, or cyclic.

2.1.1 Alkane, Alkene, and Alkyne Hydrocarbons

Saturated aliphatics (alkanes) are single-bonded compounds that occur as straight-chained (paraffins), branched-chained, and cyclic structures. The unsaturated compounds, alkenes and alkynes (olefins), have double and triple bonds, respectively, also have straight-chained, branched-,

and cyclic analogues. Although the bonds of saturated compounds induce chemically stable conditions, as opposed to the chemical reactivity of double- and triple bonds, they are more susceptible to microbial attack.

Straight-chain alkane paraffins are the largest class of compounds and comprise approximately 66% to 69% of unweathered free phase gasoline product, and olefins approximately 6% to 8% (EPA, 1990).

It is reported that alkanes are generally most readily degraded, that branching generally increases resistance to microbial attack, and that the complex cyclic compounds (cycloalkanes) are the most persistent (Atlas, 1981; Britton, 1984). Britton (1984) reports that alkanes are more susceptible to degradation than alkenes and alkynes. EPA, 1983 and Britton (1984), however, report that the straight-chain and branched alkanes are more degradable than cycloalkanes because of the complex molecular structure of the latter. EPA (1983) speculates that because the straight-chain and branched alkanes are relatively readily degradable, they do not persist in the environment, and the risk for human exposure is therefore subsequently reduced.

Bossert and Bartha (1984) report that n-alkanes, n-alkylaromatics, and aromatics in the C_{10} to C_{22} range are the most readily degradable and least toxic to degrading microorganisms. Those compounds in the C_5 to C_9 range "have a high solvent type membrane toxicity" to organisms. Those compounds above C_{22} are not readily degraded and have low toxicity. It is also reported that cycloalkanes and branched alkanes in the C_{10} to C_{22} range are more resistant to degradation than aromatics and n-alkanes due to their branched molecular configurations (Bossert and Bartha, 1984). These estimations of degradability are generalizations, however, and must be carefully evaluated due to the highly variable environmental conditions that contribute to and control hydrocarbon degradation.

2.1.2 Aromatic Hydrocarbons

Aromatic hydrocarbons are cyclic compounds having multiple double bonds and comprise approximately 24% to 27% of fresh free phase gasoline. Examples of these compounds are benzene and ethylbenzene.

In general, organic compounds with relatively high water solubilities are relatively biodegradable (EPA, 1983). The common aromatics, benzene, toluene, ethylbenzene, and xylene (BTEX), are presented as follows in order of their decreasing solubilities: Benzene 1780 mg/l, Toluene 515 mg/l, total Xylenes 162 to 198 mg/l, and Ethylbenzene 152 mg/l (EPA, 1988). Benzene, however, happens to be one of the exceptions to the general proportionality of solubility to degradability. Although benzene has a very high water solubility, it is resistant to degradation by virtue of its stable chemical structure and bonding (EPA, 1983). Benzene may actually persist in soil and groundwater for long periods of time unless the contaminated media is bio-stimulated.

Polynuclear aromatic hydrocarbons (PAHs) are complex aromatic semi-volatile compounds with

molecular structures comprised of multiple fused benzene rings. The higher the number of fused rings, the slower the decomposition of the compound unless bio-stimulation treatment is applied. PAHs are therefore less mobile and more readily sorbed in soil than the aromatic and volatile organic compounds. Naphthalene is an aromatic semi-volatile, two-ringed PAH and has a relatively low molecular weight and relatively high water solubility compared to the other PAHs. Naphthalene is the single most abundant constituent in coal tar. It occurs in petroleum fractions and is used in lubricants and motor fuels, such as motor oil and diesel.

Benzo(a)pyrene (BaP) is a complex PAH comprised of five benzene rings. BaP is carcinogenic and moderately toxic on acute exposure (Petersen, 1989b; USDH&HS, 1990). Because of its resistant chemical structure, BaP has a very low water solubility and is extremely persistent in soils. BaP is found in coal, kerosene, and petroleum products such as diesel and motor oils, and is formed during high-temperature combustion processes. BaP is classified as a B2 carcinogen (probable human carcinogen) and is considered to be the most potent carcinogen of the PAHs (USDH&HS, 1990).

Table 1 shows the ranges of volumetric percentages of benzene and other toxic petroleum-related constituents in gasoline and other types of petroleum products. Petroleum products are characterized by the types of hydrocarbons that comprise the product.

2.1.3 Gasoline

Gasoline is comprised of a complex mixture of volatile hydrocarbons ranging from C₄ to C₁₃, including aromatic and aliphatic branched and cyclic compounds that may be volatile and soluble, but are relatively resistant to degradation due to their complex molecular structure.

Table 1

Volumetric Percentages of Toxic Constituents in Petroleum Products

Constituent	Gasoline, unspecified type	Gasoline, leaded	Gasoline, unleaded	Gasoline, super unleaded	Kerosene (#1 fuel & Jet-A)	Diesel (#2 fuel)	Bunker C (#6 fuel)	Waste Oil*
Benzene	1-2 ¹ 0.16-4.66 ²	3.6 ³ , 5.2 ⁸	4.2 ³ , 4.27 ⁸ , 1.38 ⁹	5.87 ⁸	0.4 ⁶	<0.1 ² - 0.133 ⁶	0.001 ⁹	5.5 ³
Toluene	4.0 ¹ 3.64-29.1 ²	18.1 ³ , 6.0 ⁸	6.4 ⁸ , 5.8 ⁹	8.0 ⁸	1.87 ⁶	<0.1 ² - 0.933 ⁶	0.00604 ⁹	5.5 ³
Ethylbenzene	2.0-5.0 ¹ 0.48-3.8 ²	1.6 ⁸	1.87 ⁸ , 1.25 ⁹	2.0 ⁸	0.4 ⁶	<0.1 ² - 0.27 ⁶	0.00217 ⁹	--
Xylenes	15.0-24.0 ¹ 4.3-11.08 ²	7.47 ⁸	8.93 ⁸ , 6.52 ⁹	9.87 ⁸	1.2 ⁶	<0.1 ² - 0.67 ⁶	0.01342 ⁹	14.0 ³
Naphthalene	0.7 ¹ 0.12-0.65 ²	--	0.0198 ⁹	--	0.5 ³ -0.93 ⁶	0.00032 ^{**4} -0.53 ⁶ , 0.067 ⁹	0.10 ³ -0.0142 ⁹	0.14 ³
Benzo(a)pyrene	0.00007-0.00028 ²	--	--	--	--	0.00032 ⁴	0.0775 ⁹	--
EDB	0.01 ¹ , 0.00007-0.02 ^{1,2}	--	--	--	--	--	--	--
Tetraethyl lead	--	0.0018 - 0.15 ⁷	0.0000264-0.00013 ⁷	--	--	--	--	0.6-1.1 ⁵

-- data not available

* waste oil may include industrial oils as well as crankcase oil.

** total carcinogenic PAHs reported in diesel 0.00032%⁴

¹ EPA, 1988a

² California, 1987

³ Stokman, 1987

⁴ Lee, et al, 1988

⁵ Hess, 1979

⁶ Dunlap and Beckman, 1988

⁷ CBC, 1990

⁸ Robbins, 1990

⁹ EPA, 1988b

The major chemical components of gasoline are cycloalkanes (up to 3.32%), aromatic compounds (21% to 60%), straight-chain alkanes (up to 32%), and branched alkanes (up to 70%) (California, 1987; Nyer and Skladany, 1989). However, the EPA (1988) reports that most gasolines contain up to 35% by volume BTEX. Robbins (1990) reports the total aromatic constituents, BTEX, in the following percentages by volume: 20.2%, 21.4%, and 25.7% in leaded, unleaded, and premium unleaded gasolines, respectively. Toluene alone, however, may comprise up to 29.1% of unspecified types of gasoline (California, 1987; Robbins, 1990). Ethylene dibromide (EDB) constitutes approximately 0.01% of gasoline (EPA, 1988; California, 1987) and can be an indicator chemical in gasoline releases. EDB is a highly toxic known carcinogen, and a highly soluble (4310 mg/l) lead scavenger additive in gasoline. Because of its multi-purpose use, such as a fumigant pesticide, EDB in the environment should be evaluated with caution.

Gasoline contains variable amounts of tetraethyl and tetramethyl organolead. Lead is extremely persistent in the environment, and has a water solubility of 0.08 mg/l (EPA, 1988). It is also reported that in hard water, lead's solubility is 0.03 mg/l, and 0.50 mg/l in soft water (USDH & HS, 1988). The solubility of lead depends on pH, temperature, and the presence of humic material.

Lead has two valence states, Pb^{+2} and Pb^{+4} . In natural water, depending on the pH and Eh, the divalent Pb^{+2} is the stable ionic species and competes with calcium cations for sorptive sites. Under alkaline and oxidizing (high pH and Eh) hydrochemical conditions, lead has a tendency to form low solubility compounds by combining with major anions (OH , CO_3 , SO_4), forming Pb hydroxides, carbonates, sulfides, and sulfates, and precipitating from solution. In acidic, reducing conditions (low pH and Eh), lead is reduced to its +2 valence state and is mobilized into solution.

Organolead is more toxic than inorganic lead because of the ease with which organic compounds can be absorbed. The degradation of tetraethyl lead produces triethyl lead, which is more persistent in the environment. In aqueous solutions, tetraethyl lead and tetramethyl lead are adsorbed by suspended particulates, thereby extending their persistence in water. The degradation end-product is inorganic lead.

2.1.4 Diesel fuel

Diesel is comprised primarily of the heavy, straight-chained saturated aliphatic hydrocarbons (C_{10} to C_{23}) (Hess, 1979; Dunlap and Beckmann, 1988; Nyer and Skladany, 1989) that are more easily broken down and relatively less toxic than the complex aromatic ringed compounds typical of gasoline. Diesel fuel is reported to contain less than 0.1% total BTEX (California, 1987; Stokman, 1987; Guard, et al, 1983) and approximately 0.00032% total carcinogenic polynuclear aromatic hydrocarbons (PAHs), such as benzo(a)pyrene (BAP) and naphthalene (Lee, et al, 1988). Diesel may contain, however, up to 0.133 % benzene, 2% total BTEX, and up to 0.53% naphthalene (Dunlap and Beckmann, 1988).

2.1.5 Waste oil

Waste oil generally contains motor oils and various types of lubricating oils. Lubricating oils generally contain negligible amounts of non-petroleum oils, such as vegetable oils and greases. These types of oils are innocuous mixtures of fatty acid glycerides, which contribute to the total oil and grease content in waste oil (Hess, 1979).

Waste oil is a complex mixture of aromatic volatile, semi-volatile, polycyclic aromatic, and straight-chain aliphatic organic hydrocarbons. Because waste oil contains a wide variety of constituents in highly variable concentrations, there is a paucity of references concerning its composition (personal communication, American Petroleum Institute, Washington, D.C., September 1990).

It is reported that waste motor oil consists primarily of the saturated hydrocarbons, C_{21} to C_{36} , and probably higher (Hess 1979; Nyer and Skladany, 1989), with twice as many "naphthenes" (cycloalkanes) as the straight-chain and branched aliphatics, and approximately 13% by volume total aromatic hydrocarbons (Hess 1979).

Waste oil is reported to contain naphthalene concentrations ranging from 0.7% to 0.14% (Stokman, 1987; EPA, 1988), benzene concentrations ranging from 0.01% to 5.5% (Stokman, 1987), and negligible amounts of other PAHs. Combustion, however, is assumed to account for 100% volatilization of the volatile aromatic compounds in motor oil (Hess, 1979), and the constituents of concern remaining in waste oil are the PAHs and lead. Waste oil is reported to contain lead concentrations ranging from 0.6% to 1.1% by volume (Hess, 1979). Waste oil tanks are occasionally used as receptacles for a variety of solvents and other substances and should be evaluated accordingly.

Although Table 1 indicates that gasoline contains the highest percentages of the aromatic constituents and may therefore be a more toxic substance than diesel fuel or #6 fuel oil, it should not be overlooked that diesel and #6 fuel oil contain greater percentages of the carcinogenic PAHs than gasoline. For example, diesel and #6 fuel oil, may contain 0.28% and 0.05% 2-Methylnaphthalene, respectively; #6 fuel oil may contain almost 1% benzo(a)anthracene, almost 1% pyrene, and 2.12% chrysene (EPA, 1988b). While the PAHs have much higher adsorption coefficients and lower potential for migration than the aromatics, their toxicity and persistence in soils should be carefully scrutinized by those managing soils contaminated by those substances.

2.2 Regulatory Guidelines used by Various Agencies

Federally established Maximum Contaminant Levels (MCLs) for the common petroleum-related contaminants in water are currently enforced for benzene and lead. The MCLs for water were developed through a risk assessment process which considers hazards associated with acute and chronic exposure, as well as economics, treatment technology, and laboratory confidence limits.

The U.S. EPA has developed health-based guidance levels (HBGLs) for the purpose of setting protection levels for contaminants that do not have federally promulgated standards. The HBGLs for water were developed through the risk assessment process, without consideration of economic

or treatment technology factors. HBGLs are versatile because they have general application, are not site-specific, and are flexible enough to accommodate site-specific conditions. They are also conservative enough to accommodate quality assurance/quality control (QA/QC) factors that may reduce the reliability of the analytical results. The Utah State Bureau of Water Pollution Control (1989) has adopted those advisory levels as enforceable Proposed MCLs for water.

Proposed MCLs (PMCLs) are derived from MCLs and HBGLs, and consider economic factors and treatment technology. The Utah State Bureau of Water Pollution Control (1989) has adopted those advisory levels as enforceable Proposed MCLs for water.

Table 2 presents the Federal MCLs, PMCLs, and HBGLs for petroleum-related constituents in water, and the water quality criteria used in various states. Some states have imposed more stringent water quality criteria than the Federal standards. Table 3 shows the soil TPH RCLs required by various states.

California's conservative RCLs are based on achieving groundwater quality criteria more stringent than the Federal guidance levels (California, 1987) and MCLs. Stokman (1987) ran separate models for determining TPH RCLs based on achieving Federal guidance levels (HBGLs) and MCLs, and the New Jersey Department of Environmental Protection drinking water standards.

States that require additional sample analysis for the PAHs for diesel fuel and waste oil contamination include Arizona and South Dakota (Peterson, 1989; South Dakota, ARSD).

Table 2
Required and Recommended Water Quality Criteria
(ug/L, ppb)

Constituent	Federal MCL	Federal HBGL	Federal Proposed MCL	Utah	California	Arizona	New Jersey	Oregon	South Dakota	Washington
TPH	--	--	--	--	--	--	--	--	100	--
Benzene	5.0	1.3		5.0	0.70	5.0	1.0	5.0	5.0	1.0
Toluene	1000*	--	--	1000	100	2000	50	40	200	40
Ethyl-benzene	700*	--	700	700	680	680	50	30	--	20
Total Xylenes	10,000*	--	10,000	10,000	620	440	44	20	10,000	20
EDB	--	0.0005	0.05	0.05	--	0.05	--	--	--	--
Naphthalene	--	20 ²	--	20 ²	--	14,000	--	--	--	--
Benzo(a)pyrene	--	0.003	0.20	0.20	--	0.2	--	--	--	--
Lead	50	20	5.0	50	--	50	--	--	--	--
PCB ¹	0.5	0.008	0.5	0.5	--	--	--	--	--	--
Oil and Grease		--	--	10,000 ³	--	--	--	--	--	--

--not applicable or data not available

¹ Polychlorinated biphenyl

² Drinking Water Health Advisory, Office of Water, U.S. EPA, March 1990

³ Federally recommended secondary standard for discharges to surface water (personal communication, November 5, 1990, Utah BWPC)

* New federal MCLs, 40 CFR parts 141, 142, 143, January 30, 1991.

(Table revised to include * on February 28, 1991.

Table 3

TPH Soil RCLs in Various States
(mg/kg, ppm)

STATES	TYPE OF PETROLEUM RELEASE		
	Gasoline	Diesel	Waste Oil
California ¹	10, 100, 1000*	100,1000, 10000*	--
Arizona ²	100	100, measure PAHs	100
Oregon ³	40, 80, 130*	100, 500, 1000*	--
New Mexico ⁴	50	--	--
Minnesota ⁵	50	1.0	--
Oklahoma ^{4**}	0.15, 1.5, 50*	0.15, 1.5, 50*	0.15, 1.5, 50*
South Dakota ⁶	0.1, 10, 25, 50, 75, 100*	0.1, 10, 25, 50, 75, 100*; measure PAHs	0.1, 10, 25, 50, 75, 100*; measure PAHs & EP Tox metals
Idaho	100***	--	--
Nevada ⁷	100	--	--

-- data not available.

* Soil RCLs depend on site-specific criteria and environmental sensitivity of the site.

** Oklahoma allows 10 mg/kg of BTEX to be left in place at sites of the lowest environmental sensitivity.

*** Depends on depth to groundwater.

¹ California, 1987

² Arizona DEQ, 1989

³ Oregon DEQ, 1990

⁴ Simpson, 1990

⁵ Minnesota Pollution Control Agency, 1990

⁶ South Dakota Administrative Rules

⁷ Pers. comm., August 1990, November 6, 1990, Nevada Division Environmental Protection.

2.3 Determining Soil RCLs From Contaminant Transport and Fate Models

In order to estimate the concentration of TPH that can be safely left in place, and determine appropriate soil RCLs, one must consider the proportion of petroleum hydrocarbons that will attenuate in soil, as compared to those that will leach and migrate toward groundwater. TPH soil RCLs have general application and can be tailored to meet site-specific conditions. One of the most important factors in determining appropriate soil RCLs at a specific site is the best professional judgement of experienced UST scientists.

Contaminant transport and fate models combine general site conditions with compound-specific information to derive a range of numeric values. The values are then applied as cleanup levels depending on the results of the Evaluation Ranking Criteria and Leaching Potential Analysis (section 3.3.1).

The leaching potential of TPH in soil depends on many factors including the soil type, depth to groundwater, amount of rainfall, the type of petroleum product released, and the presence of onsite features that may facilitate contaminant migration. In general, compounds with low molecular weight and high solubility, such as benzene, tend to migrate easily through soil to groundwater (Oak Ridge National Laboratory, 1989). Multi-ringed compounds of high molecular weight, such as polynuclear aromatic hydrocarbons (PAHs), are not readily degradable or mobile, and tend to remain in soil for long periods of time. It is therefore necessary to consider site-specific factors and types of petroleum products when determining cleanup levels.

2.3.1 Contaminant Transport and Fate Models

This section describes how contaminant fate and transport models derive numeric output values. The values are adjusted by applying site-specific criteria to establish RCLs for petroleum-contaminated soil.

The contaminant transport and fate models predict a range of numeric values of TPH concentrations that can be left in place before benzene is leached to groundwater and attains concentrations in excess of its 5 ug/l MCL. The Evaluation Ranking Criteria (Leaching Potential Analysis) determines the environmental sensitivity of a particular site using criteria that most commonly facilitate contaminant migration. The range of numeric output RCL values resulting from contaminant fate and transport models and professional experience are then applied to the level of site sensitivity derived from the Evaluation Ranking Criteria and Leaching Potential Analysis.

Although contaminant fate and transport modeling is beyond the scope of this task, the RCL output values derived from contaminant fate and transport models run by California (1987) and Stokman (1987) have been adopted and modified by incorporating Utah site-specific criteria determined from the Evaluation Ranking Criteria.

Table 4 presents the soil RCLs derived from the various contaminant transport and fate models.

California's Models

The SESOIL (Seasonal Soil Compartment Model) and AT123D models were used by California (1987) to estimate the concentration of contaminants that can be left in place under various sensitivities of environmental conditions. The models provide the numeric framework for applying the site-specific conditions and determining the leaching potential of contaminants left in place.

The SESOIL model was initially developed by Bonazountas and Wagner (1984) for the U.S. EPA Office of Toxic Substances. SESOIL is designed for simulating the long-term movement and environmental fate of contaminants in the vadose zone. It predicts the amount of contamination that will leach into groundwater. AT123D employs LOTUS 123 to manipulate hydrogeologic parameters, the output of which is used as input data for SESOIL. California (1987) and Stokman (1987) used these models to develop soil cleanup levels.

For determining concentrations of TPH that can be safely left in place in soil, California designed their models to meet water quality criteria that are more stringent than the Federal MCLs and PMCLs.

The contaminant transport models apply the following factors for determining the leaching potential of TPH-related constituents: soil bulk density, permeability, porosity, organic carbon content, depth to groundwater, precipitation, recharge, hydraulic gradient, hydraulic conductivity, and dispersivity. Characteristics of individual constituents include solubility, adsorption coefficient, diffusion coefficient, and molecular weight. California's models applied a 0.002 percent per day biodegradation factor.

California applied the following parametric input values to the models: longitudinal dispersivity 16.4 feet; lateral dispersivity 1.64 feet; vertical dispersivity 1.64 feet; decay constant 0; and hydraulic gradient 0.03 feet/foot. Attenuation was assumed to be constant with depth. The output of the models was a range of whole number values, as follows: 0 to 1 for nondetectable levels, 1-10, 10-100, 100-1000, and up to 10,000 for diesel. Any gasoline-related value over 1000 is assumed to be slated for full evaluation and remediation (California, 1987).

Stokman's Models

Stokman (1987) also used the SESOIL and AT123D models to determine if 100 mg/kg TPH in soil would leach concentrations of BTEX and naphthalene to groundwater in excess of their applicable MCLs and HBGLs over a 10 year period of time. Stokman modeled two separate scenarios for a shaly silt and a fine sand vadose zone.

Stokman derived one set of TPH and BTEX soil RCLs by adjusting the model to achieve Federal

water quality criteria and a separate set of RCLs by using New Jersey Department of Environmental Protection water quality criteria, which is more stringent than federal standards.

Stokman's models applied parameters similar to those used by California, and included the following input values: 45 inches annual precipitation, 10 feet depth to groundwater, and an affected area of 25 x 25 x 5 feet deep.

Stokman's leaching potential models predicted that TPH concentrations of 100 mg/kg in a fine sand vadose zone would yield approximately 16 ug/L benzene in groundwater, three times the allowable level for benzene; toluene, ethylbenzene, xylene, and naphthalene were well below their MCLs. Stokman's results suggest that 30 ppm TPH left in place has the potential for leaching approximately 5.0 ppb benzene to groundwater.

EPA/Petersen's Analysis

A third method for evaluating the leaching potential of contaminants is presented by the EPA (1980b) and Petersen (1989a). In determining extraction procedure toxicity (EP Tox) levels in soils, EPA (1980b) used contaminant transport and fate models to estimate attenuation, or dilution factors in various types of soil and at varying distances from a pollutant source. EPA (1980b) suggests that a 100-fold attenuation factor is, in most cases, protective and achievable. These studies conclude that attenuation is difficult to quantify and that site-specific factors, such as rainfall, groundwater flow rates, and pumping wells, may significantly affect the applicability of the 100 attenuation factor (EPA 1980b).

Petersen's analysis applies the attenuation factor by multiplying 100 by the drinking water HBGL for a particular contaminant to derive soil cleanup levels. This method is reported to result in achievable yet protective cleanup levels, and is generally representative of a child at play and their average daily ingestion of 10 grams of petroleum-contaminated soil (Petersen, 1989a). Risk calculations for dermal and inhalation routes of exposure indicate that exposure by ingestion is orders of magnitude greater, and is thereby the most protective calculation for risk analysis (Lee, et al, 1988). The soil RCLs derived from the 100-fold attenuation have served Arizona in effectively directing corrective action.

Other Methods of Determining RCLs

Ibbotson, et. al. (1987) applied the U.S. EPA Global-82 program to estimate the concentration of gasoline-related constituents that can be safely left in place. Safe concentrations were defined as the lower 95% confidence level of the dose as it corresponds to the one-in-a-million (1×10^{-6}) lifetime risk, as calculated by the Global-82 program.

Table 4

TPH and BTEX Soil RCLs from the
Contaminant Transport and Fate Models
(mg/kg, ppm)

	TPH	Benzene	Toluene	Ethyl- benzene	Xylene	Naph- thalene
California's model ¹	10,100,1000	0.300*	0.300*	1.0*	1.0*	--**
Stokman's Model ²	<100	1.25	704	278	146.3	9863
Stokman's Model ³	<100	0.25	17.6	20.4	14.6	na
EPA/Petersen Analyses ⁴	--	0.130	200	70	1000	1400
Ibbotson, et.al. model, U.S. EPA Global-82	--	0.04-0.130	--	--	--	5400- 13960

* Cleanup levels for sites of primary and intermediate levels of environmental sensitivity. The 1989 LUFT manual requires non-detectable BTEX for the most sensitive site.

--** not applicable

¹ Based on SESOIL/AT123D models and Evaluation Ranking Criteria using California water quality criteria.

² Based on SESOIL/AT123D models using Federal water quality criteria.

³ Based on SESOIL/AT123D models using New Jersey water quality criteria.

⁴ BTEX values derived from the 100-fold attenuation factor.

3.0 Initial Screening Criteria

The initial response to an UST release is followed by staff review of information submitted by the UST owner/operator. UST staff are required to use certain screening criteria for evaluating the concentrations of contaminants observed at a site. This criteria includes the determination of compliance pursuant to R451-205 UAC, the type of product released, site-specific factors, and Evaluation Criteria pursuant to R450-101 UAC. The staff must also determine if the concentrations of contaminants at the site present a threat to human health and the environment, and decide whether or not the site warrants leaking underground storage tank (LUST) status. The initial screening can be accomplished by determining if the concentrations of contaminants exceed the soil RCL for the most environmentally sensitive site. This concentration may be referred to as the Screening Level, and LUST status is designated if the Screening Levels are exceeded for any site.

Figure 2 depicts the initial screening criteria that is applied when evaluating a release. UST staff must determine the type of product released. If the concentrations of contaminants exceed the RCLs for the most environmentally sensitive site, the release site is assigned to a project manager for technical review.

3.1 Initial Response

The federal regulations, 40 CFR Part 280, require the owner/operator to report UST releases to the implementing agency (Bureau of Environmental Response and Remediation, by legislative authority) within 24 hours of confirming a release from an UST system, take immediate action to prevent further release, and identify and mitigate any explosion hazards.

If the release is discovered during an UST system closure or a failed UST system tightness test, the owner/operator is required to collect a specific number and type of samples pursuant to R451-205 UAC. The owner/operator then must submit a Closure Notice and the laboratory analytical results of the closure samples.

3.2 Staff Review of Closure Notice and Analytical Results

UST staff reviews the submitted closure information and analytical results of samples collected during closure. If the analytical results indicate soil TPH concentrations in excess of the RCLs for the most environmentally sensitive conditions (Table 9), the site may be assigned to a project manager for technical review. The project manager checks for compliance, accuracy, and thoroughness of that information. The project manager must evaluate the site to determine its environmental sensitivity and the potential for contaminants left in place to impact human health and the environment. If the submitted information is complete and there is no evidence of contamination, the file to the case may be closed and not tracked as a release site.

If the substance released is not identified as gasoline, diesel, or waste oil, the soil RCLs presented in this document may not apply and the cleanup levels may be determined at the discretion of the Executive Secretary of the Utah Solid and Hazardous Wastes Committee. In such cases, the cleanup levels may be set using R450-101 UAC Cleanup Policy.

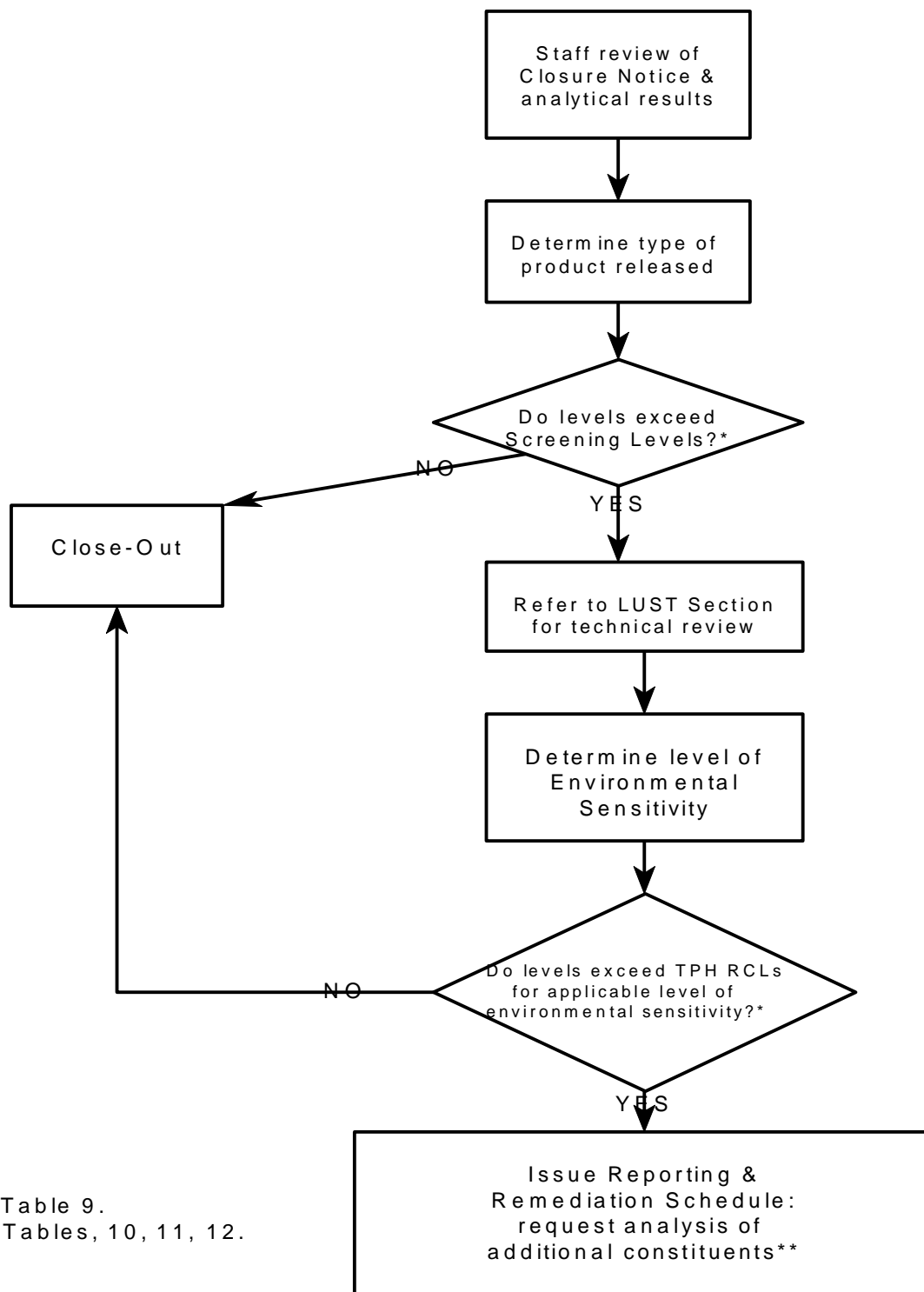
3.2.1 Determination of Compliance

The staff must determine if the closure submittal contains all of the information required by R451-205 UAC. If the information is incomplete, the owner/operator may be contacted by phone or written correspondence, or be issued a Reporting and Remediation Schedule requesting the additional required information.

3.3 Criteria for Evaluating the Closure Submittal

The owner/operator is responsible for ensuring that the work performed during the closure of an UST system is in accordance with R451-205 UAC, which includes collecting a sufficient number of samples from specific locations, determining the native soil type, and collecting a groundwater sample from a properly constructed monitor well if groundwater is encountered.

Figure 2
Initial Screening Criteria



* Use Table 9.

** Use Tables, 10, 11, 12.

UST technical review staff then use specific criteria for determining the concentration of contaminants that can be safely left in place. Those criteria are discussed in the following sections.

Section 3.3.1 describes the Evaluation Ranking Criteria and how it is essential for determining the environmental sensitivity of a specific site, and the leaching potential for TPH. Section 3.3.2 discusses the importance of determining the type of petroleum product that has been released. Section 3.3.3 describes how the soil TPH RCLs are derived, and presents the RCLs for the appropriate levels of environmental sensitivity.

3.3.1 Evaluation Ranking Criteria and Leaching Potential Analysis for Determining Soil TPH Cleanup Levels

The Evaluation Ranking Criteria is a Leaching Potential Analysis that aids in determining the environmental sensitivity of sites in Utah where petroleum releases have occurred, and the level to which the contaminated media must be cleaned up. The Criteria were developed specifically for Utah, and were compared to similar methodologies and soil RCLs used by California (1987), Oregon (1989), South Dakota (ARSD), and contaminant transport computer models (EPA, 1980b; Bonazountas and Wagner 1984; California, 1987; Stokman, 1987).

The level of environmental sensitivity of a specific site must be determined in order to estimate the leaching potential of TPH-related constituents and the concentration of TPH that can be safely left in place without adversely impacting groundwater or migrating to sensitive areas. The most important site-specific factors that contribute to contaminant leaching and migration are depth to groundwater (or distance from contaminants to groundwater), native soil type, annual precipitation, distance to wells, distance to surface water, local land use and potential receptors, and the presence of onsite utility conduits (EPA, 1980b; California, 1987; EPA, 1988b; EPA, 1990).

Each criterion is ranked on a numeric scale according to a high, medium, and low potential for migrating and/or impacting groundwater, or posing a threat to human health and the environment.

Three levels of environmental sensitivity have been selected and are representative of a variety of conditions in Utah that range from most to least conducive to contaminant leaching. Level I sites are, for example, areas characterized by any combination of factors, such as shallow depth to groundwater, highly transmissive soils in areas of moderately high rainfall, with onsite or adjacent utility conduits.

Table 5 is an abbreviated chart for the Evaluation Ranking Criteria and Final Ranking Score.

Tables 6, 7, and 8 show the equations used to assist in deriving numeric values for TPH RCLs for gasoline, diesel, and waste oil-contaminated soil. Table 9 presents the soil RCLs for TPH and associated with gasoline, diesel, and waste oil, and oil and grease associated with waste oil, for the three levels of environmental sensitivity, and based on the total points accumulated from the

Evaluation Criteria Ranking Score.

The suggested guidelines are designed to meet the requirements of Utah's cleanup policy R450-101 UAC, and are not intended to preclude other site-specific criteria or background water quality criteria. Additional factors that may influence the soil TPH RCL are the volume of contaminated media, background water quality, or other applicable criteria. In addition, this document is intended for use in setting standards for petroleum-related contaminants in soil, and is not intended to supersede background aquifer water quality characteristics pursuant to the Utah Groundwater Quality Protection Regulations and aquifer classification criteria.

1. Distance from Contamination to Groundwater: The depth to groundwater, in feet below land surface, must consider the highest seasonal average. In some cases, depth to groundwater and subsurface contamination are both relatively deep. The depths to groundwater shown below also apply to the distance from the lowest vertical extent of contamination to groundwater. In addition, recharge areas are considered to be as environmentally sensitive as the lowest distance from contamination to groundwater. Sites located in recharge areas may therefore be scored 20 points.

Distance to Groundwater (ft)	Ranking Score
>100	0
100 to 75	4
50 to 75	8
25 to 50	12
10 to 25	16
<10, or recharge area	20

2. Native Soil Type: The predominant site lithology and native soil type will be determined by soils classified according to the Unified Soil Classification. The level of environmental sensitivity is determined by the permeability of the soil and the ease with which contaminants migrate through the soil.

Native Soil Type	Ranking Score
<p>a. Low permeability</p> <p>(clay, shale, fat clay, high plasticity clay, elastic silt, low plasticity silt, lean clay, silty clay, sandy clay, silty or clayey fine sand, very fine sand, gravelly clay, unfractured igneous and metamorphic rocks, and consolidated, cemented sedimentary rocks;</p> <p>USC= Pt,OH,CH, MH,OL,CL,ML).</p>	0
<p>b. Moderate permeability</p> <p>(clayey sand, poorly graded sand-clay mixtures, silty sand, poorly graded sand-silt mixtures, moderately fractured igneous and metamorphic rocks, moder-ately permeable limestone;</p> <p>USC=SC, SM).</p>	10
<p>c. High permeability</p> <p>(fine sand, silty sand, sand, gravel, gravelly sand, clayey gravel, gravel-sand-clay-silt mixtures, silty gravel, highly fractured igneous and metamorphic rocks, vesicular igneous rocks, cavernous or karstic limestone;</p> <p>USC=SM,SP,SW,GC, GM,GP,GW).</p>	20

3. Annual Precipitation: The average annual precipitation in a specific area must be identified in order to evaluate the effects of recharge and potential for mobilization of contaminants. The values for average annual precipitation are specific for Utah, and represent the annual average precipitation in the desert, mountain, and intermediate geographical regions in the state (Waddell, et.al., 1987). Precipitation information shall be collected from the nearest national meteorological weather station. Onsite ground cover (e.g. concrete or asphalt) that might prevent infiltration of precipitation is not considered due to the potential for irregularities and fractures in the ground cover that could allow infiltration.

Annual Precipitation	Ranking Score
<10 inches	0

Annual Precipitation	Ranking Score
10 to 20	5
>20	10

4. Distance to Nearest Municipal Water Production Well: A municipal water production well is assumed to be a well designed to supply groundwater for community consumption. The distances from subsurface contamination to a municipal production well, and the corresponding scores shown below, are based on local and regional knowledge of the properties of the deep confined aquifers that occupy many of the basins in Utah, and those which are tapped by production wells (Clark, et.al., 1990; Herbert, et.al., 1990, Hely, et.al., 1971). Using the Theis equation for a well producing from a confined aquifer (Bouwer, 1978; Freeze and Cherry, 1979; Driscoll, 1986), the effective radii (r) of one-mile (5280 feet), one-quarter of a mile (1320 feet), and 500 feet induced by a high-capacity municipal well are calculated by applying a pumping rate (Q) of 1500 gallons per minute for 183 days (1/2 year) (t), from an aquifer with a hydraulic conductivity (K) of 100 feet per day (ft/day, clean sand), and an aquifer thickness (or perforated interval, b) of 500 feet, transmissivity (T) of 50,000 ft²/day (Clark, et.al., 1990; Herbert, et.al., 1990, Hely, et.al., 1971), and a storage coefficient (S) of 0.001. The radii of influence demonstrated by the Theis equation are corroborated by the Thiem equation for a pumped or flowing well in a confined aquifer (Bouwer, 1978; Freeze and Cherry, 1979). EPA (1980) also suggests a critical minimum distance of 500 feet from a point source of contamination (a landfill, for example) and a downgradient drinking water well.

Theis Equation:
$$h_2 - h_1 = \frac{Q}{4 \pi T} * W(u) \quad u = \frac{r^2 S}{4 T t}$$

Thiem Equation:
$$Q = \frac{2 \pi K b (h_2 - h_1)}{\ln(r_2 - r_1)}$$

Distance to Nearest Production Well (ft)	Ranking Score
>5280	0
5280 to 1320	8
1320 to 500	10
<500	15

5. Distance to Other Wells: Other wells will be defined as domestic, irrigation, and stockwatering wells that generally have less capacity, and thus smaller radius of influence, than municipal wells. The critical distances of contamination from a low capacity well were also derived using the Theis and Thiem equations, and are based on an aquifer properties as described in hydrologic information publications for Utah (Hely, et.al., 1971, Waddell, et.al., 1987, Clark, et.al., and Herbert, et.al., 1990). Those properties include a hydraulic conductivity of 100 ft/day, aquifer thickness (or perforated interval) of 100 feet, transmissivity of 10,000 ft²/day, pumping rate (Q) of 200 gallons per minute, and a pumping period (t) of 8 hours, which would result in a critical radius of influence of 300 feet (Driscoll, 1986), and maximum radius of influence of one-quarter mile (1320 feet).

Distance to Other Well (ft)	Ranking Score
>1320	0
300 to 1320	5
<300	10

6. Distance to Surface Water: Surface water bodies include perennial rivers, streams, creeks, irrigation canals and ditches, lakes, and ponds. The critical distance of contamination to a surface water body is based on experimental modeling by Stokman (1987). The model evaluated the changes in benzene concentration in groundwater at varying distances from a release of unleaded gasoline. The model predicted that an initial benzene concentration of approximately three times the MCL was reduced to below the MCL at a distance of 300 feet from the source. Although this distance may not be applicable in all cases, 300 feet is considered to be an appropriate critical distance feet between a source of contamination and surface water. Approximately three times the most sensitive distance is 900 feet, which is rounded up to 1000 feet.

Distance to Surface Water (ft)	Ranking Score
>1000	0
300 to 1000	2
<300	5

7. Potentially Affected Populations: The score for affected populations is based on the number of potential receptors within a three-mile radius of a release site, using census plot information. A three-mile radius is based on the ability of contaminants to travel three miles via utility conduits, or by other means. The potentially affected populations include residents, employees, campers, and others who regularly enter the area.

Affected Populations	Ranking Scores
<100	0
100 to 3000	10
> 3000	20

8. Presence of Onsite or Adjacent Utility Conduits or Wells: Utility conduits include water distribution lines, sewer lines, septic tanks, buried electrical lines, and any other conduit that may facilitate contaminant migration. Water wells may also facilitate contaminant migration by acting as conduits due to faulty surface seals, or due to drawdown induced by pumping.

Presence of Adjacent or Onsite Utility Conduits or Wells	Ranking Score
Not Present	0
Unknown	14
Present	15

9. Summation of Ranking Criteria to Determine Environmental Sensitivity and Cleanup Levels

The summation of all of the above ranking scores will yield one value which shall be used to determine the appropriate soil cleanup levels on a case-by-case basis. The sensitivity levels are as follows:

- Level I Sensitivity: For scores totaling >65
- Level II Sensitivity: For scores totaling 40 to 65
- Level III Sensitivity: For scores totaling <40

> = greater than; < = less than

Table 5
Evaluation Ranking Criteria and Ranking Score

Site-Specific Factors	Ranking Score	Final Ranking Score
Distance to Groundwater (feet): >100 100 to 75 75 to 50 50 to 25 25 to 10 <10, or recharge area	0 4 8 12 16 20	
Native Soil Type: Low permeability Mod. permeability High permeability	0 10 20	
Annual Precipitation (inches) <10 10 to 20 >20	0 5 10	
Distance to Nearest Municipal Production Well (feet) >5280 1320 to 5280 500 to 1320 <500	0 8 10 15	
Distance to Other Wells (feet). >1320 300 to 1320 <300	0 5 10	

Distance to Surface Water (feet) >1000 300 to 1000 <300	0 2 5	
Affected Populations <100 100 to 3000 >3000	0 10 20	
Presence of Nearby Utility Conduits Not Present Unknown Present	0 14 15	
Final Score		

3.3.2 Type of Product Released

The soil TPH RCLs for a specific site are determined by the substance stored in the UST(s). The various types of petroleum products behave very differently in various types of media. The type of product must therefore be known and identified in order to ascertain appropriate soil TPH RCLs for a particular release. This document addresses releases of gasoline, diesel, and waste oil products only.

Releases of unspecified or unknown products types maybe subject to the evaluation of all constituents that could be contained in an UST. In addition, a commingled plume will be subject to cleanup using the most stringent RCLs for the product types.

3.3.3 RCLs for TPH in Utah for Gasoline, Diesel, and Waste Oil-Contaminated Soil

Soil RCLs are site-specific criteria that remediation must satisfy in order to keep exposure to potential receptors at or below a specific level ("action level"). This level is determined by the concentration of a chemical in a particular medium that, when exceeded, may present a

significant health risk (Duah, 1989). RCLs can assume this definition and be applied in technical reviews when site-specific conditions are evaluated in conjunction with the applicable constituent concentrations, on-site lithology, depth to groundwater, proximity to surface water, and local affected populations.

Studies and references on the subject of standardizing TPH soil RCLs are few, and contaminant transport and fate modeling is beyond the scope of this document. However, the methodology and results of the three contaminant transport and fate models have been modified by applying the Evaluation Ranking Criteria developed for specific conditions in Utah, and the best professional judgement of experienced scientists in order to derive appropriate soil RCLs for release sites in Utah.

Estimating the RCL for TPH in soil is based on the known carcinogenicity of benzene, and its potential for leaching from TPH-contaminated soils. A leaching potential can be derived by back-calculating the percentage of benzene in the various petroleum products and applying the 100-fold attenuation factor (Battelle, 1976; EPA, 1980) to derive the concentration of TPH in soil from which a concentration of benzene would leach into water and attain a maximum concentration of 5.0 ug/l. The calculations for gasoline, diesel, and waste oil are shown in Tables 6, 7, and 8. It is important to bear in mind that the values derived from the calculations have been evaluated and modified using the contaminant transport and fate models and the judgement of experienced UST environmental scientists.

The following sections provide detailed discussions of the justifications for the RCLs.

3.3.3.1 Gasoline

The calculation in Table 6 shows how soil TPH RCL values of 10 mg/kg, 20 mg/kg, and 50 mg/kg are derived by applying the minimum, mean, and maximum percentages of benzene in gasoline of 1%, 2.5%, and 5%. Use of the MCL for benzene as the basis for the calculation is considered appropriate for a conservative estimation of RCLs. California's 10 mg/kg TPH in soil (for the most environmentally sensitive areas) is corroborated by calculating a 5% volumetric percentage of benzene in gasoline. As previously stated, however, California's 10 mg/kg RCL is based on achieving a water quality standard for benzene of 0.7 ppb (Table 2). A soil TPH RCL of 10 mg/kg is very stringent and may even impede corrective action.

Oregon's soil RCLs for TPH in soil were derived from the equation in Table 6 then modified by applying the best professional judgement and Oregon-specific conditions to arrive at a soil TPH RCL of 40 mg/kg for the most environmentally sensitive site.

The results of Stokman's (1987) models conclude that, under conditions most conducive to leaching, 30 mg/kg TPH can be safely left in place without adversely impacting human health and the environment. UST reviews in Utah indicate that soil containing concentrations at or below 30 mg/kg have not been documented to leach concentrations of benzene to groundwater in

excess of benzene's 5 ug/l MCL, nor has human health and the environment been endangered by leaving 30 mg/kg TPH in place. Similarly, groundwater contamination has been demonstrated at sites where 50 mg/kg TPH is in place. It can therefore be concluded that a soil TPH RCL of 30 mg/kg can be safely left in place in the most environmentally sensitive sites. This conclusion is based on a review of values used by other regulatory agencies, the application of the results of contaminant transport and fate models, and the best professional judgement of the UST staff. In addition, staff have found that the concentrations of gasoline-related TPH that can be safely left in place increases by an approximate factor of three with decreasing levels of environmental sensitivity.

If concentrations of TPH exceed the RCL for the applicable level of sensitivity, the analysis of BTEX and lead should be conducted. The information concerning the RCLs for the additional constituents is presented in section 4.0.

Table 6

Calculation for the Leaching Potential of Benzene
from TPH associated with Gasoline-Contaminated Soil

MCL for Benzene in Water		Attenuation Factor		Benzene in Soil		1%,2.5% and 5% Benzene in Gasoline		Maximum Level of TPH left in place
5 ppb	*	100	=	500	/	0.01	=	50,000 ppb 50 ppm
5 ppb	*	100	=	500	/	0.025	=	20,000 ppb 20 ppm
5 ppb	*	100	=	500	/	0.05	=	10,000 ppb 10 ppm

3.3.3.2 Diesel

Because diesel fuel is comprised primarily of readily degradable, relatively low toxicity hydrocarbons, the soil TPH RCLs are higher values than those for gasoline. A soil TPH RCL of 380 ppm for diesel is derived by applying the maximum reported concentration of 0.133% benzene in diesel to the leaching potential equation (Table 7). However, experience with diesel releases in environmentally sensitive areas indicate that concentrations exceeding 100 ppm may adversely impact groundwater. It is therefore suggested that a 100 ppm value be set for the most

environmentally sensitive sites, and that the calculated value of 380 mg/kg be rounded down to 300 mg/kg for sites of intermediate sensitivity. It may be necessary that diesel-related TPH concentrations in soil exceeding the applicable RCL be subject to further evaluation, including additional sampling for the analysis of BTEX, naphthalene, and benzo(a)pyrene. The information concerning the RCLs for additional diesel-related constituents is presented in section 4.0.

Table 7

Calculation for the Leaching Potential of Benzene
from TPH associated with Diesel-Contaminated Soil

MCL for Benzene in Water		Attenuation Factor		Benzene in Soil		0.133% Benzene in Diesel		Maximum Level of TPH left in place
5 ppb	*	100	=	500	/	0.00133	= =	375,940 ppb 380 ppm

3.3.3.3 Waste Oil

Since waste oil is comprised largely of constituents that have a propensity for binding in soil and not leaching to groundwater, the soil RCLs for waste oil-contaminated soil are higher than those for gasoline. A calculated soil RCL of 380 mg/kg for waste oil-related TPH is derived from the equation in Table 8, and is based on the assumption that waste oil may contain as much benzene as diesel (0.133%). However, because waste oil and waste oil USTs contain a wide variety of constituents in highly variable concentrations, it is recommended that a lower RCL be established. Experience with waste oil releases in areas of varying degrees of environmental sensitivity concludes that waste oil-related TPH of 100 mg/kg is generally protective of sites exhibiting the most environmentally sensitive characteristics, and that the calculated value of 380 mg/kg (rounded down to 300) is more appropriate for sites of intermediate environmental sensitivity.

If oil and grease are analyzed rather than TPH, it is suggested that the soil RCL for oil and grease be 300 mg/kg for the most environmentally sensitive sites. Although TPH and oil and grease concentrations are not proportional, TPH is generally less than 50 mg/kg in soil when oil and grease values are as low as 400 mg/kg in soil. In addition, the method used to analyze for oil and grease (413.1) is subject to positive interference by non-mineral hydrocarbons, such as animal and vegetable oils and greases.

It may be necessary that waste oil-related TPH concentrations in soil exceeding the applicable RCL be subject to further evaluation, including additional sampling for the analysis of TPH and/or oil and grease, lead, BTEX, and volatile organic compounds (VOCs). PCBs should also be evaluated if there is reason to suspect that a waste oil UST may have received transformer oils or unidentified substances. The information concerning the RCLs for the additional constituents is presented in section 4.0.

If TPH is analyzed, it is necessary that EPA analytical method 418.1 be used. This method can detect the heavy hydrocarbons that typically comprise waste oil (C_{21} to C_{36}). In general, method 8015 will not detect hydrocarbons greater than C_{30} and is therefore not suitable for determining TPH concentrations in waste oil.

Table 8

Calculation for the Leaching Potential of Benzene
from TPH associated with Waste Oil-Contaminated Soil

MCL for Benzene in Water		Attenuation Factor		Benzene in Soil		0.133% Benzene in Waste Oil		Maximum Level of TPH left in place
5 ppb	*	100	=	500	/	0.00133	= =	375,940 ppb 380 ppm

Table 9 presents the soil TPH RCLs for UST release sites in Utah for the three levels of environmental sensitivity, which are determined from the Evaluation Ranking Criteria in section 3.3.2. A site will be assigned to a project manager for technical review if the initial soil TPH results exceed the level established for the most environmentally sensitive conditions. This is referred to as the Screening Level.

Table 9

Levels of Environmental Sensitivity and Recommended Cleanup Levels
for Petroleum-Contaminated Soils (mg/kg or ppm)

	Level I	Level II	Level III
Total Points	>65	40 to 65	<40
TPH, gasoline*	30	100	300
TPH, diesel**	100	300	500
TRPH, waste oil***	100	300	500
Oil and Grease, waste oil ^{++****}	300	600	1100

* May require analysis of BTEX and lead.

** May require analysis of BTEX and PAHs. TRPH = Total Recoverable Petroleum Hydrocarbons.

*** May require analysis of TRPH and/or oil and grease, BTEX, PAHs, lead, solvents, and PCBs.

⁺ Requires EPA analytical method 418.1.

⁺⁺ Requires EPA analytical method 413.1.

3.4 Activities Subsequent to Initial Review by the State

Upon evaluating the site, determining the level of environmental sensitivity, and ascertaining the concentration of TPH that can be left in place, the Staff determines whether or not the concentration of contaminants left in place must be remediated. If the levels of TPH exceed the values in Table 9 for the applicable level of environmental sensitivity, remediation is necessary, and the owner/operator must follow the guidelines presented in the following section 4.0 and submit a series of reports according to 40 CFR, part 280.60.

3.4.1 Extenuating Circumstances for Determining Cleanup Levels

Extenuating circumstances for a specific site may impede an accurate site evaluation and characterization. Altering the RCL for a site may be necessary if other factors are deemed important. These factors may include the volume of contaminated media, background water quality, soil texture, soil moisture content, age of the release, and economic and technological

criteria pursuant to R450-101. If those circumstances are determined to exist at a site, and prove to have significant bearing on the leaching potential and migration of contaminants, the values presented in this document may be modified and more appropriate values established by the UST staff.

4.0 Issuance of Reporting and Remediation Schedule

If the submitted closure information indicates that contamination may require cleanup, the UST staff issues a Reporting and Remediation Schedule that identifies the required reports, specific elements that must be addressed in the reports, and the compliance due dates of the reports. In addition, further sampling and analysis of specific constituents is required for sites exhibiting concentrations of TPH in excess of the appropriate RCLs. Figure 3 shows the process for further evaluation of a release site following UST closure.

4.1 Information Required

The Reporting and Remediation Schedule identifies the required reports and their due dates pursuant to 40 CFR part 280.60. The Schedule also identifies the detailed elements that must be addressed and documented for each required report. If soil TPH concentrations exceed the values shown in Table 9 for the applicable level of environmental sensitivity, it is necessary that additional constituents be analyzed depending on the type of product released.

4.2 Compliance Dates

Upon receipt of the Reporting and Remediation Schedule, the owner/operator is required to submit an Abatement and Site Check report within 20 days, an Initial Site Characterization report within 45 days, a Free Product Removal report within 45 days, and an Investigation for Soil and Groundwater Cleanup and Corrective Action Plan within a time frame specified by the Staff.

4.3 Applicable Cleanup Levels for Site Remediation

A site that exhibits TPH concentrations in excess of the applicable RCL for a given level of environmental sensitivity will be subject to additional sampling and analysis of hazardous constituents that are commonly associated with the particular type of product that is released. Sections 4.3.1, 4.3.2, and 4.3.3 identify the constituents that must be evaluated for gasoline, diesel, and waste oil releases, respectively. If the type of product released is unknown or undisclosed, sampling and analysis for all of the additional constituents identified in sections 4.3.1, 4.3.2, and 4.3.3 will be required. Figure 3 depicts the sequence in which site evaluations

are made and appropriate RCLs are determined, depending on the type of product released.

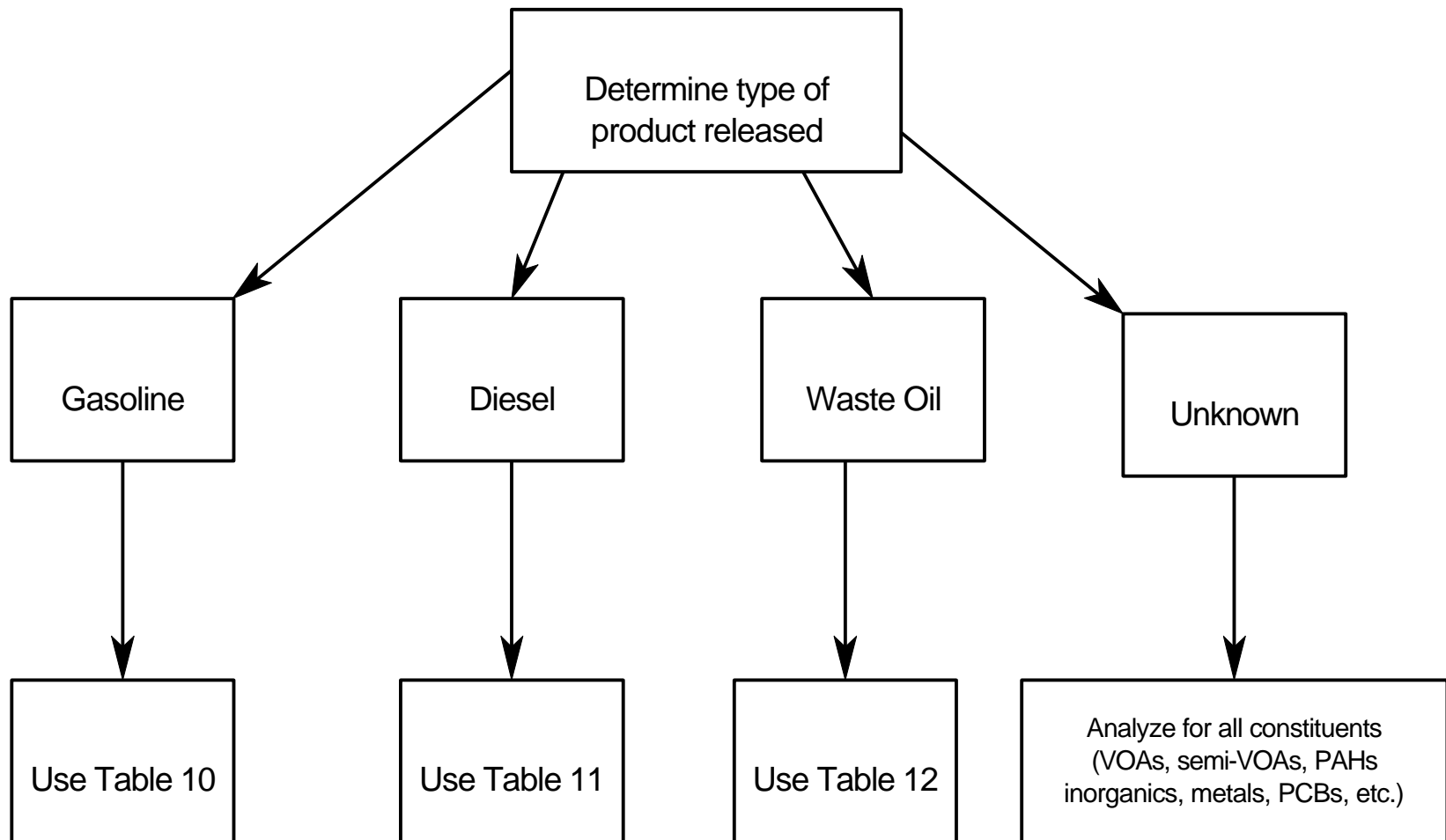
The soil RCLs for toluene, ethylbenzene, xylene, lead, naphthalene, benzo(a)pyrene, and PCBs are derived from the EPA (1980) analysis that suggests a 100-fold attenuation factor for organic and inorganic constituents soil RCLs. The attenuation factor is multiplied by the MCL or HBGL of the constituent in water to derive what is reported to be a conservative soil RCL that is believed to be most protective of human health and the environment (Petersen, 1989a; Petersen, 1989b). The calculated values are then rounded to one significant figure in order to facilitate easier use of the RCLs.

Due to the uncertainty associated with establishing an RCL for benzene, it is suggested that the cleanup level for benzene be 200 ug/kg (0.200 mg/kg). The fact that this value may be protective is supported by the values derived from California's (1987) and Stokman's (1987) models, which based the leaching potential of benzene on achieving water quality standards more stringent than the Federal criteria. Moreover, 200 ug/kg is the detection limit for analyzing BTEX in soil using EPA analytical method 8020 for aromatic volatile organic compounds (American West Analytical Laboratories, personal communication, August 1990; Chemtech Laboratory, person communication, November 1990). Achieving a detection limit lower than 200 ug/kg requires a more costly analytical method (EPA method 8240). It is therefore anticipated that a benzene soil RCL of 200 ug/kg meets the objectives of R450-101, which requires the consideration of economics and technological feasibility when determining cleanup levels.

In the absence of a published reference dose for naphthalene in soil, a conservative concentration of naphthalene in soil may be derived from its HBGL in water (14,000 ug/l) times the 100 attenuation factor, and rounded down to 1000 mg/kg. Ibbotson, et. al.'s (1987) models predicted that naphthalene concentrations of 5400 mg/kg may be safely left in place in areas of high probability of exposure, and that up to 13,960 mg/kg may be left in place at sites where the risk for exposure is low.

BaP's HBGL of 0.2 ug/l in water is multiplied by the 100-fold attenuation factor to attain a soil RCL of 20 ug/kg. Ibbotson (1987) estimated that 4 ug/kg to 10 ug/kg may be safely left in place.

Figure 3
Further Evaluation of Contamination



4.3.1 Gasoline

Because gasoline contains appreciable amounts of BTEX and lead, for which toxicity data is well-documented, it is necessary that the presence and concentrations of those constituents be ascertained. If the initial TPH values exceed the RCL, then the concentrations of the other listed gasoline-related constituents must be analytically determined.

Table 10 shows the allowable concentrations of gasoline-related compounds that can be safely left in place, depending on the level of environmental sensitivity of a specific site. The lead concentration for the most environmentally sensitive site of 100 mg/kg is based on an estimation of the background soil concentration in Utah (Shaklette and Boerngen, 1984). Use of the 100-fold attenuation factor yields a soil RCL of 5 mg/kg, which is considerably lower than the estimated background concentration. Since it is not reasonable to attempt to clean up lead to below background levels, the 100 mg/kg soil RCL for lead is recommended.

Table 10

Soil RCLs for TPH and other Gasoline-Related Constituents

Constituents (mg/kg)	Level I	Level II	Level III
TPH	30*	100*	300*
Benzene	0.200	0.300	1.0
Toluene	100	300	900
Ethylbenzene	70	200	600
Xylenes, total	1000	3000	10,000
Lead	100	300	1000

* If concentrations of TPH exceed these values for the applicable level of sensitivity, measure the additional constituents.

4.3.2 Diesel

Diesel contains variable concentrations of naphthalene and benzo(a)pyrene, both of which are potent carcinogens. If the initial TPH values exceed the RCL, then the concentrations of the other listed

diesel-related constituents must be analytically determined.

Table 11 shows the allowable concentrations of diesel-related compounds that can be safely left in place, depending on the level of environmental sensitivity of a particular site.

Table 11
Soil RCLs for TPH and other Diesel-Related Constituents

Constituents (mg/kg)	Level I	Level II	Level III
TPH	100*	300*	500*
Benzene	0.200	0.300	1.0
Toluene	100	300	900
Ethylbenzene	70	200	600
Xylenes, total	1000	3000	10,000
Naphthalene	2.0	5.0	10.0
Benzo(a)pyrene	0.02	0.06	0.20

* If concentrations of TPH exceed these values for the applicable level of sensitivity, measure the additional constituents.

4.3.3 Waste Oil

Because waste oil contains a wide variety of hazardous constituents in highly variable concentrations, it is therefore necessary that waste oil releases be fully characterized. If the initial TPH values exceed the RCL, then the concentrations of the other listed waste oil-related constituents must be analytically determined.

Table 12 shows the most common constituents associated with waste oil releases and the applicable soil RCLs for those constituents.

Table 12

Soil RCLs for TRPH and other Waste Oil-Related Constituents

Constituents (mg/kg)	Level I	Level II	Level III
TRPH	100*	300*	500*
Oil and Grease	300	600	1100
Benzene	0.200	0.300	1.0
Toluene	100	300	900
Ethylbenzene	70	200	600
Xylenes	1000	3000	10,000
Lead	100	300	1000
Solvents	--**	--	--
Naphthalene	2.0	5.0	10.0
Benzo(a)pyrene	0.02	0.06	0.20
PCBs	50	50	50

* If concentrations of TRPH exceed these values for the applicable level of sensitivity, measure the additional constituents.

--** To be determined by the Executive Secretary, depending on the constituent.

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